Smartphone Ownership, Age of Smartphone Acquisition, and Health Outcomes in Early Adolescence

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abstract

OBJECTIVES: Given concerns regarding health implications of adolescent smartphone use, we tested associations of smartphone ownership and age of smartphone acquisition with depression, obesity, and insufficient sleep in early adolescence. We hypothesized that smartphone ownership, especially at a younger age, would be associated with worse health outcomes.

METHODS: The sample included 10 588 participants from the Adolescent Brain Cognitive Development Study. Mixed-effects logistic regression models tested associations of smartphone ownership and age of first smartphone acquisition, reported by caregivers, with depression, obesity, and insufficient sleep at age 12 years. Among participants who did not own smartphones at age 12 years, we tested associations of recent acquisition of smartphones with outcomes in the subsequent year. Models were adjusted for demographic and socioeconomic variables, ownership of other devices, pubertal development, and parental monitoring.

RESULTS: At age 12 years, compared with not owning a smartphone (n = 3849), smartphone ownership (n = 6739) was associated with higher risk for depression (odds ratio [OR] 1.31, 95% CI: 1.05–1.63), obesity (OR 1.40, 95% CI: 1.20–1.63), and insufficient sleep (OR 1.62, 95% CI: 1.46–1.79). Younger age of smartphone acquisition was associated with obesity and insufficient sleep (for each earlier year of acquisition, OR 1.09, 95% CI: 1.02–1.16, and OR 1.08, 95% CI: 1.02–1.12, respectively). At age 13 years, among 3486 youth who did not own a smartphone at age 12 years, those who had acquired a smartphone in the past year (n = 1546) had greater odds of reporting clinical-level psychopathology (OR 1.57, 95% CI: 1.12–2.20) and insufficient sleep (OR 1.50, 95% CI: 1.26–1.77) compared with those who had not (n = 1940) after controlling for baseline mental health and sleep. Results were consistent across several sensitivity analyses.

CONCLUSIONS: Smartphone ownership was associated with depression, obesity, and insufficient sleep in early adolescence. Findings provide critical and timely insights that should inform caregivers regarding adolescent smartphone use and, ideally, the development of public policy that protects youth.

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WHAT'S KNOWN ON THIS SUBJECT: Most American youths acquire a smartphone during early adolescence. Previous research has linked general screen use around this age, but not specifically smartphone use, to impairments in mental health, body weight, and sleep patterns.

WHAT THIS STUDY ADDS: Among US youths of early adolescent age, smartphone ownership and earlier age of smartphone acquisition is associated with higher rates of depression, obesity, and insufficient sleep. These findings highlight the need to consider health risks when teens gain smartphone access.

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INTRODUCTION

Smartphone ownership is a *rite of passage* for youths, and, in the United States, approximately one-half of children will have their own smartphone by age 11 years.[1] Smartphones provide ready and immediate access to schoolwork, social networks, internet browsing, gaming, and social media. Given the potential for negative exposures (eg, bullying, explicit content) coupled with the fact that many 8- to 12-year-old individuals are spending approximately 4 to 6 hours per day using screens, inclusive of smartphones,[2] and the potential adverse health associations of screen time,[3,4] there is growing concern regarding how smartphone use affects mental and physical health among young people. Accordingly, the American Academy of Pediatrics (AAP) and the American Academy of Child and Adolescent Psychiatry (AACAP) have established guidelines to support families in instituting healthier boundaries, delineating recommended screen time limits, preferred parental controls, and optimal parental modeling practices.[5] To our knowledge, however, there are no guidelines regarding the appropriate age at which youths should first own a smartphone.[6,7]

The decision to provide a child with their own smartphone is often initiated as a matter of necessity, allowing communication with caregivers and addressing safety concerns. Although the intended use for smartphones may be circumscribed, there is a natural drift wherein youth begin to use their smartphones for other activities (eg, socialization, education).[6] Most prior research has focused on the consequences of excessive, addictive, or problematic smartphone use,[8–12] reflecting a preoccupation and relative loss of control, reported among 3% to 35% of youths.[13] Problematic smartphone use is associated with a wide range of negative outcomes, including adverse mental health consequences (eg, depression), increased sedentary behaviors, and diminished sleep.[9,14,15] However, it is not evident whether simply owning a smartphone, accounting for the age of ownership, in childhood and early adolescence potentiates risks for negative health consequences.

As smartphone ownership among children becomes more ubiquitous, there is a critical need for data to inform families regarding the decision of when to provide their child with access to smartphones, as well as to guide public health policy. Thus, this study aimed to examine how acquiring a smartphone relates to health outcomes in early adolescence. Accordingly, we used data from the Adolescent Brain Cognitive Development (ABCD) Study, which tracks US youths annually from late childhood. We hypothesized that smartphone ownership and earlier acquisition of smartphones would be associated with depression, obesity, and insufficient sleep.

METHODS

Participants

ABCD Study participants were enrolled across 21 sites throughout the United States and were assessed from late childhood into adolescence.[16] Therefore, the baseline assessment was completed at a mean age of approximately 10 years, with follow-up assessments each subsequent year (eg, 1-year follow-up at a mean age of approximately 11 years, 2-year follow-up at a mean age of approximately 12 years, 3-year follow-up at a mean age of approximately 13 years). The ABCD Study conducts in-person structured clinical computerized assessments, whereas body mass index (BMI) is measured by taking height and weight of youth study participants. ABCD data release 5.1, which included 5 assessments conducted between 2016 and 2022 (baseline to 4-year-follow-up, age range of 9–16 years), was used. Smartphone ownership was first assessed in the 2-year follow-up assessment; therefore, we used data from this assessment and the subsequent assessments. Sample description is summarized in Supplemental Table S1. Note that data on less than one-half of the sample were available for the 4-year follow-up assessment. These data were used only in supplemental sensitivity analyses. The ABCD Study protocol was approved by the University of California San Diego institutional review board (IRB), and analyses were exempted from review by the Children's Hospital of Philadelphia IRB. We adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Smartphone Ownership

Smartphone ownership was assessed annually starting at the 2-year follow-up assessment based on caregiver response to the question "Does your child have their own cellphone?" and to the follow-up question regarding device type. Participants with an iPhone or Android were considered as owning a smartphone. Age of receiving a smartphone was identified based on caregiver response to the question "How old was your child when he/she got their own cellphone?" First-time smartphone ownership in the past year was considered for youths whose caregiver responded "no" regarding cellphone ownership at the 2-year follow-up but later responded "yes" at the 3-year follow-up.

Health-Related Outcomes

To enhance clinical interpretability and effect size interpretation, we used binary outcomes in our main analyses. Mental health outcomes included lifetime depression diagnosis based on the "Kiddie Schedule for Affective Disorders and Schizophrenia Child Psychiatric Diagnostic Interview" (KSADS)[17] at the 2-year and 4-year follow-up assessments

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and on clinical-threshold level (T-score ≥ 65)[18] of psychopathology at the 3-year follow-up (which did not include KSADS assessment) based on the self-reported Brief Problem Monitor (BPM)[19] scale, which assesses internalizing, externalizing, and attention symptoms.[18] Obesity was determined by BMI (kilograms per meters squared, based on weight/height measurements during study assessment) greater than the 95th percentile.[20] Insufficient sleep was defined as youth-reported sleep duration of less than 9 hours per night.[21] Supplemental Material eMethods provide further details on outcome measures.

Statistical Analyses

We conducted 3 sets of analyses to test our hypotheses. Analysis 1 tested associations of smartphone ownership with outcomes at age 12 years (2-year follow-up). Analysis 2 examined how the age at which participants first acquired a smartphone (in years; continuous measure) was associated with health outcomes at age 12 years, focusing specifically on the subgroup that already owned a smartphone by that age. Analysis 3 investigated the associations between first acquiring a smartphone in the past year and outcomes at age 13 years. Analysis 3 included only participants without smartphones at age 12 years, creating a cohort that compared those who subsequently acquired smartphones vs those who remained without smartphones by age 13 years, ensuring that both groups shared a common preexposure period. This allows preexposure outcome measures, assessed at age 12 years (psychopathology, obesity, insufficient sleep), to be adjusted for as covariates, providing a higher quality of causal evidence.

Mixed-effects logistic regression models ("mixed models") used smartphone ownership (Analysis 1), age of first smartphone acquisition (Analysis 2), or past-year smartphone acquisition (Analysis 3) as independent variables, with depression, obesity, and insufficient sleep as outcome variables. Analysis 3 used clinical-threshold psychopathology as the outcome instead of depression because the KSADS was not used at the 3-year follow-up assessment. Mixed models accounted for the hierarchical nature of the data using nested random effects for family (when siblings were enrolled) and research site. To correct for the testing of 3 outcomes, we applied a *P* value threshold of 0.017 (0.05/3). For each outcome, we estimated a base model that included age and sex assigned at birth and an adjusted model that covaried for confounders, including household income, parental education, participants' race and ethnicity (caregiver report), pubertal status (pre-, early, mid-, late, and post-pubertal)[22], and parental monitoring (average of 5 youth-reported items,[23] each rated from 1, never, to 5, always),[23] which is associated with the studied outcomes.[24–26] To enhance specificity of results to smartphone ownership, this model adjusted for ownership of other devices (eg, tablet, laptop, iPod, smartwatch). Covariates are described in the Supplemental Material eMethods. Note that the rationale to include race and ethnicity as covariates[27] was intended to address potential confounding owing to differences in smartphone ownership (exposure variable) and health outcomes among racial and ethnic groups in the ABCD Study.[28,29] We explored sex differences by adding the interaction term (product) of the exposure and sex to the adjusted model. Models used listwise deletion of missing data. Data missingness is provided in Tables 1 and 2. Because no analysis included multiple time points with smartphone ownership, adjustments for dropout and intention-to-treat analyses were not required. Comparison of participants who were included vs those who were excluded because of missing exposure data (<10%) is provided in Supplemental Table S2.

For each model, we report the odds ratio (OR), exponentiated regression coefficient, 95% CI value, and two-sided *P* value. In Analysis 2, coefficients were transformed to reflect a positive relationship between younger age and adverse outcome (depression, obesity, insufficient sleep) by using the inverse of the OR and 95% CI values. We used R (version 4.5.0, R Project for Statistical Computing) package lme4 for statistical models and ggplot package for data visualization.

Sensitivity Analyses

First, we re-estimated models excluding participants with problematic smartphone use. Because there is no gold-standard tool to quantify problematic smartphone use,[30] we used the Mobile Phone Involvement Questionnaire,[31] which probes problematic smartphone use patterns in the ABCD Study[32] (detailed in the Supplemental Material eMethods).

Because our analysis of observational data depends on an assumption of no unobserved confounding between exposed vs unexposed conditions, we conducted E-value sensitivity analysis[33] to quantify the degree of unobserved confounding required to explain our results in the absence of a treatment effect (detailed in the Supplemental Material eMethods).

We re-estimated models with continuous outcome measures (overall psychopathology, BMI, hours of sleep) using linear mixed models.

Finally, we re-estimated mixed models of Analyses 1 and 2 using longitudinal data from the 2-year, 3-year, and 4-year follow-up assessments.

RESULTS

Smartphone Ownership

Among youths who reported owning a cellphone, nearly all (6739 of 7010; 96.1%) owned a smartphone (iPhone or Android; Table 1). Smartphone ownership rose steadily across the assessments: 63.6% (6739 of 10 588) at the

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TABLE 1. Comparison of Youths Who Own a Smartphone With Those Who Do Not by the 2-Year Follow-Up Assessment Wave

	Overall Sample	Does Not Own a Smartphone	Owns a Smartphone	Uncorrected *P* Value	Missing Data, %
n	10 588	3849	6739	NA	NA
Smartphone type, iPhone	NA	NA	4313	NA	NA
Smartphone type, Android	NA	NA	2426	NA	NA
Demographic characteristics					
Age at 2-y follow-up, mean (SD)	12.02 (0.67)	11.83 (0.63)	12.13 (0.66)	<.001	0.01
Late/post-pubertal (2-y follow-up), n (%)	2122 (20.04)	480 (12.47)	1642 (24.37)	<.001	5.37
Female sex assigned at birth, n (%)	5028 (47.49)	1623 (42.17)	3405 (50.53)	<.001	0.03
White race, n (%)	7985 (75.42)	3161 (82.13)	4824 (71.58)	<.001	0.17
Black race, n (%)	2153 (20.33)	492 (12.78)	1661 (24.65)	<.001	0.17
Asian, n (%)	668 (6.31)	272 (7.07)	396 (5.88)	.02	0.17
American Indian and Alaska Native race, n (%)	365 (3.45)	97 (2.52)	268 (3.98)	<.001	0.17
Mixed race, n (%)	1282 (12.11)	413 (10.73)	869 (12.90)	.001	0.17
Hispanic ethnicity, n (%)	2067 (19.52)	621 (16.13)	1446 (21.46)	<.001	1.17
Household income,[a] mean (SD)	7.54 (2.31)	7.86 (2.11)	7.35 (2.40)	<.001	8.03
Parental highest education,[b] n (%)				<.001	0.19
High school or below	449 (4.24)	135 (3.51)	314 (4.66)	NA	NA
High school graduate	976 (9.22)	229 (5.95)	747 (11.08)	NA	NA
Post-high school education	2571 (24.28)	713 (18.52)	1858 (27.57)	NA	NA
Bachelor's	2738 (25.86)	1060 (27.54)	1678 (24.90)	NA	NA
Master's or above	3834 (36.21)	1708 (44.38)	2126 (31.55)	NA	NA
Ownership of other devices					
Tablet, n (%)	4696 (44.35)	1896 (49.26)	2800 (41.55)	<.001	0
Laptop, n (%)	4026 (38.02)	1009 (26.21)	3017 (44.77)	<.001	0
iPod, n (%)	1144 (10.80)	719 (18.68)	425 (6.31)	<.001	0
Smartwatch, n (%)	619 (5.85)	109 (2.83)	510 (7.57)	<.001	0
Clinical characteristics at 2-y follow-up					
Psychopathology symptoms, mean (SD)	53.71 (5.64)	53.35 (5.46)	53.91 (5.73)	<.001	11.46
Clinical-threshold psychopathology, n (%)	906 (8.56)	289 (7.51)	617 (9.16)	<.001	11.46
Lifetime depression diagnosis, n (%)	604 (5.70)	174 (4.52)	430 (6.38)	<.001	0.71
BMI, kg/m^2, mean (SD)	20.75 (4.99)	19.84 (4.43)	21.30 (5.21)	<.001	16.10
Obesity, n (%)	1649 (15.57)	454 (11.80)	1195 (17.73)	<.001	16.13
Sleep duration, mean (SD), h	9.12 (1.26)	9.40 (1.15)	8.97 (1.29)	<.001	0.96
Insufficient sleep (<9h), n (%)	4372 (41.29)	1194 (31.02)	3178 (47.16)	<.001	0.96

Abbreviations: BMI, body mass index; NA, not applicable.

Univariable comparisons were conducted for descriptive purposes to compare youths who did vs those who did not own a smartphone: Student *t* test for normally distributed continuous variables, Mann-Whitney U test for nonnormal continuous variables, and χ^2 test for categorical variables. If the expected frequencies in any cell of the contingency table were less than 5, we used Fisher's exact tests.

[a] Income is expressed as the mean of the values from 10 self-reported income brackets: (1) <$5000; (2) $5000 to 12 000; (3) $12 000 to 16 000; (4) $16 000 to 25 000; (5) $25 000 to 35 000; (6) $35 000 to 50 000; (7) $50 000 to 75 000; (8) $75 000 to 100 000; (9) $100 000 to 200 000; and (10) >$200 000.

[b] Parental education represents the highest level of education attained by either parent.

2-year follow-up (mean age of 12.02 years), 77.2% (7602 of 9853) at the 3-year follow-up (mean age of 12.91 years), and 89.1% (4094 of 4593) at the 4-year follow-up (mean age of 14.08 years). The median (IQR) age of first smartphone acquisition was 11 (10, 11) years (range, 4–13; Figure 1).

Analysis 1: Smartphone Ownership and Health Outcomes at Age 12 Years

Compared with their peers who did not own smartphones, participants who owned smartphones tended to be slightly older, were at a more advanced pubertal stage, were more likely to be female, were more likely to identify as Black race

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TABLE 2. Comparison of Youth Without Smartphones at 2-Year Follow-Up: Those Who Acquired a Smartphone by 3-Year Follow-Up vs Those Who Did Not

	Overall Sample	No Smartphone at Follow-Up	Owns a Smartphone at Follow-Up	Uncorrected *P* Value	Missing Data, %
n	3486	1940	1546	NA	NA
Smartphone type, iPhone	NA	NA	1017	NA	NA
Smartphone type, Android	NA	NA	529	NA	NA
Demographic characteristics					
Age at 2-y follow-up, mean (SD)	11.82 (0.63)	11.79 (0.62)	11.85 (0.64)	.006	0.03
Late/post-pubertal (2-y follow-up, n (%)	416 (11.93)	203 (10.46)	213 (13.78)	.004	4.96
Female sex assigned at birth, n (%)	1458 (41.82)	775 (39.95)	683 (44.18)	.01	0.03
White race, n (%)	2897 (83.10)	1640 (84.54)	1257 (81.31)	.02	0.2
Black race, n (%)	421 (12.08)	200 (10.31)	221 (14.29)	<.001	0.2
Asian, n (%)	252 (7.23)	164 (8.45)	88 (5.69)	.002	0.2
American Indian and Alaska Native race, n (%)	94 (2.70)	53 (2.73)	41 (2.65)	.98	0.2
Mixed race, n (%)	383 (10.99)	220 (11.34)	163 (10.54)	.51	0.2
Hispanic ethnicity, n (%)	552 (15.83)	276 (14.23)	276 (17.85)	.004	1.49
Household income,[a] mean (SD)	7.94 (2.09)	8.00 (2.00)	7.87 (2.19)	.09	6.63
Parental highest education,[b] n (%)				<.001	0.2
High school or below	111 (3.18)	52 (2.68)	59 (3.82)	NA	NA
High school graduate	187 (5.36)	87 (4.48)	100 (6.47)	NA	NA
Post high school education	614 (17.61)	299 (15.41)	315 (20.38)	NA	NA
Bachelor's	985 (28.26)	554 (28.56)	431 (27.88)	NA	NA
Master's or above	1582 (45.38)	941 (48.51)	641 (41.46)	NA	NA
Clinical characteristics at 2-y follow-up					
Psychopathology symptoms, mean (SD)	53.31 (5.46)	53.17 (5.38)	53.48 (5.57)	.11	11.42
Clinical-threshold psychopathology, n (%)	266 (7.63)	140 (7.22)	126 (8.15)	.44	11.42
Lifetime depression diagnosis, n (%)	150 (4.30)	86 (4.43)	64 (4.14)	.73	0.72
BMI, kg/m^2, mean (SD)	19.76 (4.34)	19.44 (4.07)	20.14 (4.62)	<.001	12.79
Obesity, n (%)	408 (11.70)	198 (10.21)	210 (13.58)	.005	12.82
Sleep duration, mean (SD), h	9.40 (1.14)	9.47 (1.12)	9.30 (1.15)	<.001	0.86

Abbreviations: BMI, body mass index; NA, not applicable.
Univariable comparisons were conducted for descriptive purposes: Student *t* test for normally distributed continuous variables, Mann-Whitney U test for nonnormal continuous variables, and χ^2 test for binary measures. If the expected frequencies in any cell of the contingency table were less than 5, we used Fisher's exact tests.
[a] Income is expressed as the mean of the values from 10 self-reported income brackets: (1) <$5000; (2) $5000 to 12 000; (3) $12 000 to 16 000; (4) $16 000 to 25 000; (5) $25 000 to 35 000; (6) $35 000 to 50 000; (7) $50 000 to 75 000; (8) $75 000 to 100 000; (9) $100 000 to 200 000; and (10) >$200 000.
[b] Parental education represents the highest level of education attained by either parent.

or of Hispanic ethnicity, and were more likely to be from households with lower income and lower parental educational attainment (Table 1). Participants with smartphones reported more depression, obesity, and insufficient sleep (Table 1). Correlations among psychopathology, BMI, and sleep were small (Pearson's |r| values ≤ 0.20, all $P < .001$; Supplemental Figure S1).

In adjusted models (Figure 2A; Supplemental Tables S3–S5), owning a smartphone was associated with depression (OR 1.31, 95% CI: 1.05–1.63, $P = .016$), obesity (OR 1.40, 95% CI: 1.20–1.63, $P < .001$), and insufficient sleep (OR 1.62, 95% CI: 1.46–1.79, $P < .001$).

Analysis 2: Age of First Smartphone Acquisition and Health Outcomes at Age 12 Years

In adjusted models (Figure 2B; Supplemental Tables S6–S8), younger age of first smartphone acquisition was associated with obesity (for each earlier year of acquisition, OR 1.09, 95% CI: 1.02–1.16; $P = .007$) and insufficient sleep (OR 1.08, 95% CI: 1.02–1.12, $P = .005$), but not with depression (OR 1.03, 95% CI: 0.94–1.12; $P = .503$). Note that results from the base model, which only covaried for age and sex, showed an association of earlier age of smartphone ownership with depression, but this did not

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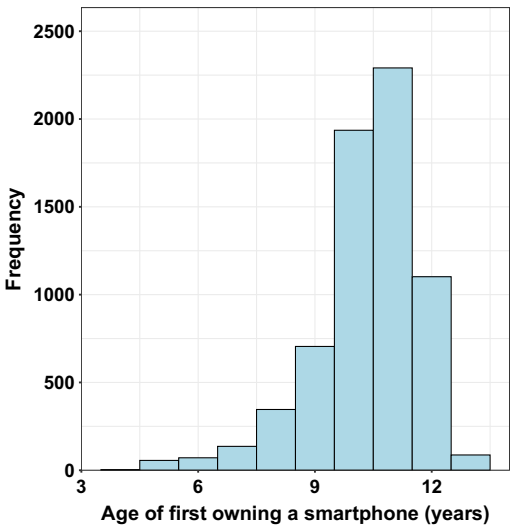


FIGURE 1.
Distribution of age of smartphone acquisition. Histogram depicting the distribution of age at which ABCD Study participants first owned a smartphone as reported at the 2-year follow-up ABCD assessment wave. Abbreviation: ABCD, Adolescent Brain Cognitive Development.

satisfy the *P* value threshold (OR 1.08, 95% CI: 1.0–1.15; $P = .046$).

Analysis 3: Recent (Past-Year) Acquisition of a Smartphone and Health Outcomes at Age 13 Years

We analyzed data from 3486 youth who did not own smartphones at the 2-year follow-up and who also participated in the 3-year follow-up, when 1546 had acquired a smartphone and 1940 had not. Table 2 details comparison of the groups. In adjusted models (Supplemental Tables S9–S11), youth who acquired a smartphone by the 3-year follow-up were more likely to reach clinical levels of psychopathology (OR 1.57, 95% CI: 1.12–2.20; $P = .009$; Figure 3) and to sleep less than 9 hours per night (OR 1.50, 95% CI: 1.26–1.77; $P < .001$; Figure 3), with no statistically significant difference in obesity (OR 1.57, 95% CI: 0.82–3.04; $P = .176$; Figure 3), compared with those who did not.

Sex Differences

We did not detect significant interactions with sex in any of the smartphone exposures.

Sensitivity Analyses

Analyses excluding participants who engage in problematic smartphone use yielded similar results to main analyses in direction and in statistical significance in all adjusted models (Supplemental Table S12). E-value analyses addressing unobserved confounding run on fully adjusted models suggested that implausibly strong unmeasured confounders would be required to explain away the observed associations (Supplemental Table S13). Analyses that used continuous outcomes (overall psychopathology BPM score, BMI, hours of sleep; Supplemental Tables S14–S22) and analyses that included longitudinal data from the 2-year, 3-year, and 4-year follow-up assessment waves (Supplemental Figure S2, Supplemental Tables S23–S28) revealed similar results in direction and statistical significance as main analyses, except for smartphone-by-sex interaction that became significant in association with

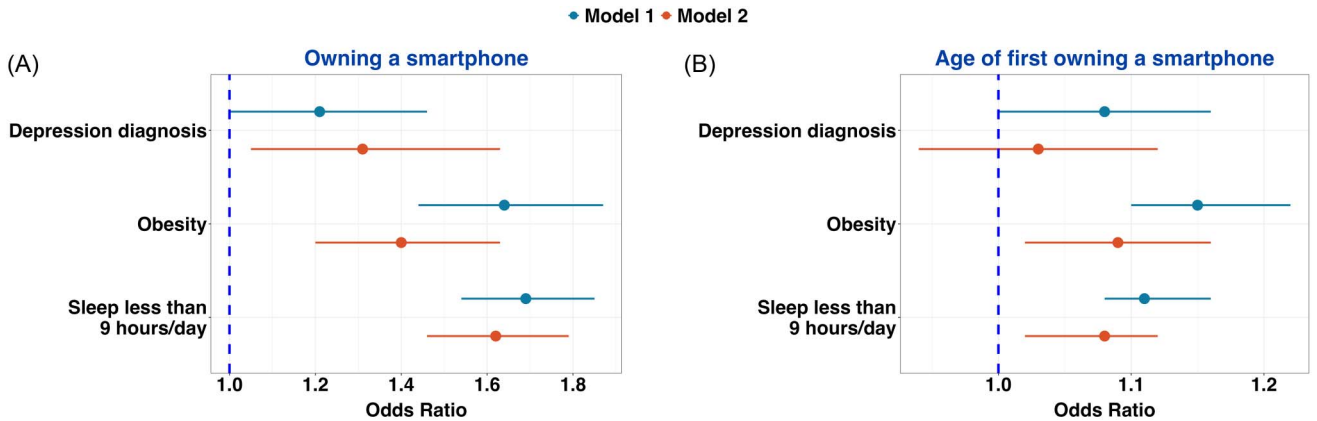


FIGURE 2.
(A) Association of smartphone ownership and (B) age of first smartphone acquisition with depression, obesity, and insufficient sleep as captured at the 2-year follow-up assessment wave of ABCD Study (age 12 years). Model 1 adjusted for age and sex. Model 2 further adjusted for race, ethnicity, income, parent education, ownership of other devices (eg, tablet, laptop, iPod, smartwatch), pubertal status, and parental monitoring. Dots represent OR and 95% CI values. Vertical dashed lines represent the null hypothesis for no association between smartphone ownership and outcome. Note that, for visualization purposes, coefficients in panel B were transformed to reflect a positive relationship between younger age and adverse outcome (more depression, more obesity, insufficient sleep) by using the inverse of the OR and 95% CI values.
Abbreviations: ABCD, Adolescent Brain Cognitive Development; OR, odds ratio.

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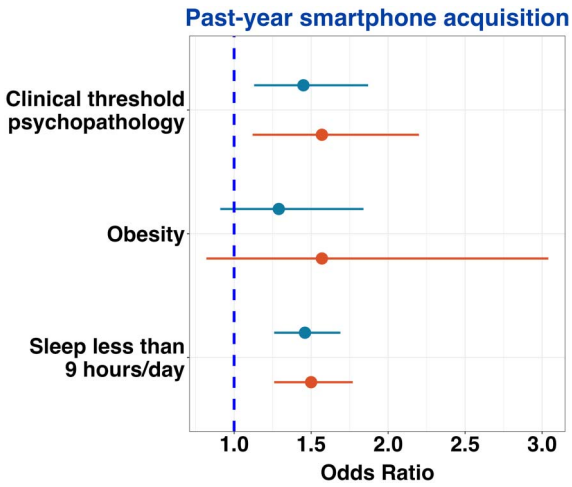


FIGURE 3.

Association of first smartphone acquisition over the past-year with clinical-threshold psychopathology, obesity, and insufficient sleep as captured at the 3-year follow-up assessment wave of ABCD Study (age 13 years). Model 1 adjusted for age and sex.

Model 2 further adjusted for race, ethnicity, income, parent education, ownership of other devices (eg, tablet, laptop, iPod, smartwatch), pubertal status, parental monitoring, and the measurement of the index outcome a year earlier, ie, at the 2-year follow-up assessment.

Psychopathology was measured with the self-reported BPM (age and sex standardized T-score), clinical threshold was considered for BPM score greater than or equal to 65. Dots represent OR and 95% CI values. Vertical dashed lines represent the null hypothesis for no association between past-year smartphone acquisition and outcome.

Abbreviations: ABCD, Adolescent Brain Cognitive Development; BPM, brief problem monitor; OR, odds ratio.

sleep (Supplemental Table 25; interaction $P = .001$), with girls showing stronger associations between smartphone ownership and insufficient sleep than boys.

DISCUSSION

In this large-scale, multisite study of US youths of early adolescent age, we provide converging evidence for adverse associations of smartphone ownership with health outcomes, accounting for several demographic, socioeconomic, and parental factors. Smartphone ownership at age 12 years was related to depression, obesity, and insufficient sleep (Analysis 1). Earlier age of smartphone acquisition was associated with obesity and insufficient sleep at age 12 years (Analysis 2). Recent (past-year) first-time acquisition of smartphones by age 13 years was associated with clinical-threshold psychopathology and insufficient sleep, even when accounting for psychopathology and sleep in the prior year (Analysis 3). Results appear specific to smartphones, as our models accounted for ownership of other devices including tablets, laptops, iPods, and smartwatches. These findings contribute to a growing body of research indicating that an earlier age of smartphone ownership may be linked to poorer mental health outcomes. Prior studies have reported that early smartphone acquisition is associated with greater psychological distress among Spanish teens[34] and that receiving a smartphone before age 13 years is associated with worse social and emotional health in young adulthood compared with those who received a smartphone after age 13 years in a multinational sample.[35] Notably, the only US study on this topic, to our knowledge, focused on Hispanic youths with low socioeconomic status with overweight or obesity and found no adverse association between smartphone ownership and either mental health or sleep.[36] This contrast highlights that findings from a narrow population may not apply broadly, strengthening the generalizability of our findings that were derived from a diverse US cohort from a multisite study.

No clear evidence exists to explain the deleterious associations between smartphone ownership and youth development. However, there is evidence that smartphone use contributes to fragmented attention, increased checking behaviors (which may impact relationships), and extended use (particularly in the evenings), which may lead to both mental and physical health challenges and less sleep,[9,10] especially during a period of development during which many youths may not have sufficiently mature self-regulatory skills to make optimal choices regarding their smartphone use.[37] Importantly, our results are separable from problematic smartphone use, as our sensitivity analyses that excluded youths with problematic smartphone use suggest that smartphone ownership, even when not rising to the level of problematic use, may negatively impact adolescent mental and physical health, which has substantial public health implications.

A key finding is that an earlier age of first smartphone acquisition was associated with higher rates of obesity and insufficient sleep at age 12 years in models that adjusted for age, sex, and multiple confounders. Association of earlier age of smartphone ownership with higher rates of depression when adjusting for age and sex ($P = .046$) did not satisfy our P value threshold. We highlight the developmental context of these results. Prior literature that focused on addictive or excessive smartphone use has suggested that smartphone ownership around childhood or early adolescence may displace time spent on in-person interactions,[38] physical activity,[39] and restorative sleep,[40] key foundations for adolescent health. Notably, although the effect sizes for the age of first smartphone acquisition are small (with ORs for all 3 outcomes around 1.1 for each earlier year of ownership), adolescence is a sensitive period during which even modest subclinical mental health symptoms, overweight, and sleep problems can have long-term health consequences into adulthood.[41–43] Thus, small effect sizes at the individual level may translate to substantial public health significance. Another important developmental consideration involves sex differences during this age range, which coincide with the transition to puberty. Previous

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research in older adolescents has suggested that girls may experience stronger adverse effects of smartphone use, particularly in relation to mental health outcomes such as depression.[14] However, our exploratory analyses did not detect significant smartphone ownership by sex differences in association with depression in early adolescence. It is possible that such differences emerge later in adolescence, coinciding with the increase in depression rates among girls following the onset of puberty.[44] Note that our sensitivity analysis that leveraged data from multiple time points, increasing the number of observations, did reveal a significant smartphone-by-sex interaction in association with impaired sleep, suggesting greater susceptibility among girls. Future longitudinal work from early to late adolescence should reexamine sex differences in the ways that teens use their smartphones and how this relates to health outcomes.

Given our findings, it is evident that a concrete framework is needed to advise on childhood and early adolescent smartphone ownership to support the healthier development of youth. There are existing tools available to gauge youth readiness. For example, the AAP has developed an easily accessible questionnaire, ie, the PhoneReady Questionnaire,[45] which is a thoughtful instrument addressing a range of key youth (eg, need, judgement, impulsiveness, accountability) and parental factors (eg, readiness to impose boundaries) to consider prior to determining whether a child is ready to have a smartphone. Although the AAP and AACAP offer other *common-sense* guidelines for instituting safer practices, empirical research is needed to establish clearer guidelines specific to the following: (1) optimal age of ownership, (2) type of phone (eg, starter phone with more limited capabilities), and (3) uses (eg, limiting to texts, phone calls, restricting access to specific apps).

Study strengths include a large longitudinal cohort from diverse communities, but there are also notable limitations. The focus of this study was on smartphone ownership, but it did not provide insight into *what* youth were doing on their smartphones. Factors such as patterns of use and exposure to adverse content may contribute to health outcomes in ways that are distinct from age. Additionally, although our findings largely persisted when accounting for parental monitoring, there may be other important, unexplored factors that buffer against negative health outcomes. Because this study used observational data (a randomized placebo-controlled trial would not have been possible), we cannot be certain that unmeasured factors are not already more prevalent among youth without smartphones, prompting caution when drawing causal conclusions from our findings. We address the research question within these limitations via converging analyses, careful inclusion of key confounders, and sensitivity analysis for unobserved confounding.

Although our findings may signal a need for public policy changes, we are not advocating for restrictions on youth access and ownership of smartphones. Rather, we highlight the need for further research to better understand the adverse effects of smartphone ownership during the transition from childhood to adolescence, a developmental period that already presents a high risk for psychiatric disorders[46,47] and sleep problems.[43,48] More broadly, smartphone ownership offers unique challenges because it may grant youths unfettered access to a world for which they may not be ready, without the discipline to effectively manage their own use. Like youths' diet, media consumption (eg, television, social media), and relationships (eg, with peers, adults), smartphone ownership requires dedicated oversight. This is particularly true because there may be various adverse consequences and challenges for certain youths who *do not* own smartphones, which underscores the need to protect these youths who require smartphones and support families as they embark on this rite of passage.

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ABBREVIATIONS

AAP: American Academy of Pediatrics
AACAP: American Academy of Child and Adolescent Psychiatry
ABCD: Adolescent Brain Cognitive Development
BMI: body mass index
BPM: Brief Problem Monitor

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IRB: institutional review board
KSADS: Kiddie Schedule for Affective Disorders and Schizophrenia Child Psychiatric Diagnostic Interview

OR: odds ratio
STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

Dr Auerbach contributed to study conceptualization and writing the first draft of the manuscript. All authors substantially contributed to and approved the final version of the manuscript. Data used in the preparation of this article were obtained from the Adolescent Brain Cognitive Development Study (https://abcdstudy.org), held in the National Institute of Mental Health Data Archive and available for researchers on application (https://nda.nih.gov/abcd/request-access). Analytical code describing all analyses is available at the following link: https://github.com/barzilab1/ABCD_smartphone_health.

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